Works-in-Progress: A Replicable Model for Integrating Entrepreneurial Mindset Learning into a Junior-Level Engineering Design Course

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1. Introduction

Engineering programs increasingly recognize the need to prepare students not only with strong technical skills, but also with the mindset and behaviors needed to navigate ambiguity, integrate diverse perspectives, and create value for real users and stakeholders. Entrepreneurial Mindset Learning (EML), as defined by the Kern Entrepreneurial Engineering Network (KEEN), provides a structured framework to support this preparation through the development of curiosity, connections, and creating value. Importantly, creating value is not treated solely as a late-stage outcome of design, but as a lens through which problems are initially framed, opportunities are identified, and stakeholder needs are interpreted. [1], [2]

Junior-level design courses represent a critical transition point in the undergraduate curriculum. At this stage, students possess foundational technical knowledge but often lack experience applying that knowledge to open-ended, ill-defined problems. This Works-In-Progress paper presents the development and preliminary assessment of a replicable model for explicitly integrating EML into a junior-level electro-mechanical design course. Unlike prior iterations in which EML principles were implicitly embedded, this redesigned course overtly introduces entrepreneurial mindset concepts and intentionally aligns course activities, modules, and assessments with KEEN outcomes.

The purpose of this paper is to (1) describe the course structure and EML integration strategy, (2) present indirect assessment results from student surveys and reflections, and (3) demonstrate how students engaged in opportunity recognition, iterative validation, interdisciplinary collaboration, and value creation.

2. Course Context and Design Framework

2.1 Course Context

Explicit metacognition plays a critical role in entrepreneurial mindset development because it helps students make their learning processes visible, evaluate the effectiveness of their strategies, and connect experiences across design iterations. By intentionally reflecting how and why they made decisions, interpreted evidence, or responded to setbacks, students deepen conceptual understanding and strengthen their ability to transfer insights to new or uncertain contexts.

Structured metacognitive prompts also support productive engagement with failure, reinforce ownership over learning, and enhance communication of design reasoning to peers and stakeholders. More importantly, explicit metacognition helps surface otherwise “invisible” cognitive behaviors such as curiosity, perspective seeking, and value-oriented thinking, making them accessible for instruction and assessment within KEEN-aligned experiential learning environments. [3]-[6]

All engineering students at XX University are required to complete a three-credit junior-level design course prior to enrolling in the senior capstone experience. The course focuses on the collaborative development of an electro-mechanical system and emphasizes key professional engineering skills, including problem definition, teamwork, communication, and project management.

Beginning in Fall 2025, the course was redesigned to explicitly incorporate EML. Students were introduced early in the semester to the KEEN framework and its three core competencies: curiosity, connections, and creating value. Course activities were framed using entrepreneurial language, and students were asked to engage in metacognitive reflection on how their behaviors aligned with entrepreneurial thinking.

Within this course redesign, value creation is introduced during the earliest stages of problem identification. Students are encouraged to articulate who benefits from the problem being addressed, why the issue matters, and what meaningful impact might look like before generating technical solutions. This framing views value not as an afterthought, but as a guiding criterion for opportunity recognition.

2.2 Entrepreneurial Mindset Integration Strategy

The EML integration follows a deliberate sequence: [1]

1. Opportunity Recognition through challenge selection
2. Curiosity through exploration of unfamiliar domains
3. Connections through collaborative and interdisciplinary modules
4. Iteration and Validation through testing, failure, and redesign
5. Creating Value through stakeholder-focused design decisions
6. Public Communication and Reflection through posters and presentations

Seven experiential learning modules scaffold these behaviors across the semester. Individual reflections, snapshot poster presentations, and final product reports serve as assessment artifacts.

Replicability in this model is achieved through a consistent module structure, explicit KEEN framing, common reflection prompts, and assessment artifacts that can be adopted without changes to course credit hours or facilities. A detailed implementation of this approach has also been disseminated through an Engineering Unleashed Card, providing a structured and transferable framework for adoption by other instructors [7]. Each module was designed to make entrepreneurial behaviors explicit, reinforcing opportunity identification, iteration, validation, and value creation as integral elements of engineering design rather than ancillary skills.

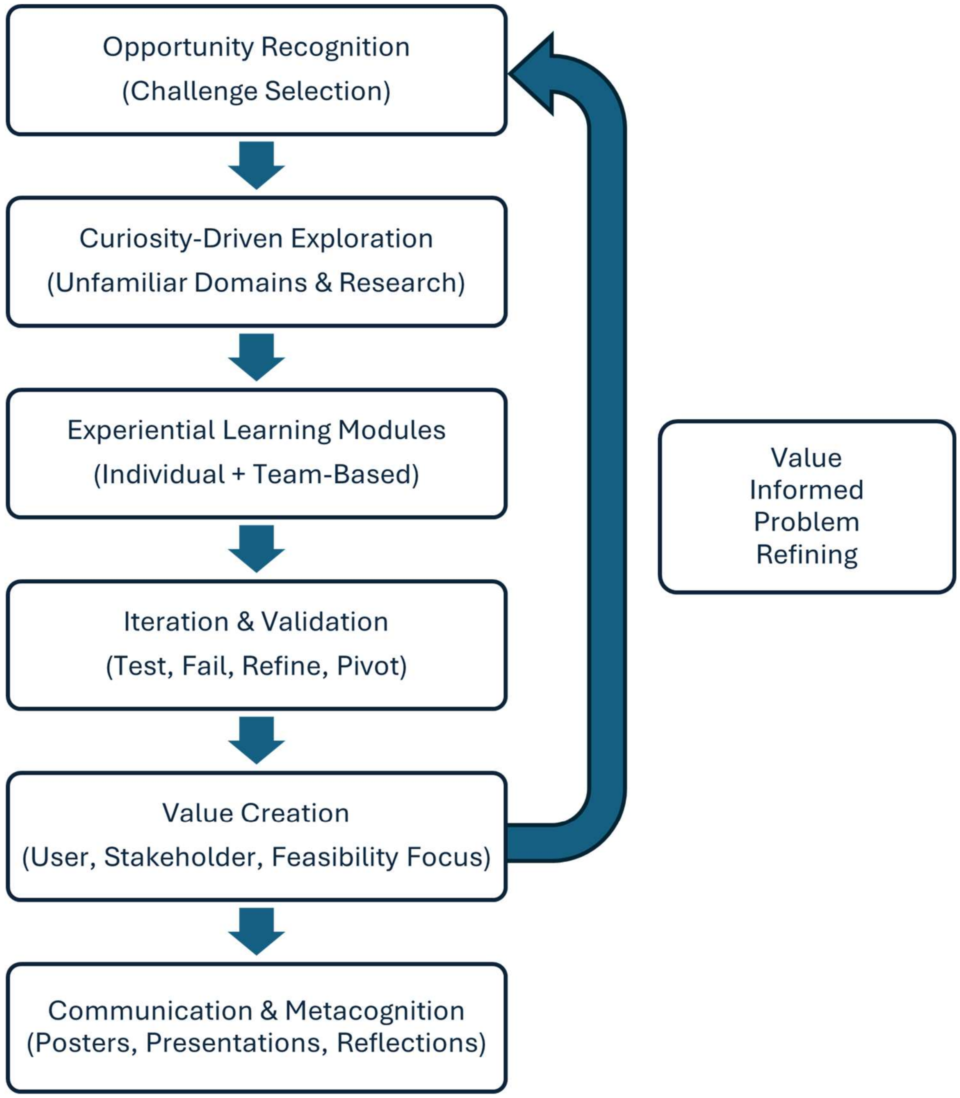

Figure 1. Course model illustrating the explicit integration of Entrepreneurial Mindset Learning (EML) within a junior-level electro-mechanical design course. Although organized sequentially, stakeholder-informed value framing recursively shapes problem definition, alternative generation, and design refinement across modules.

Although "Creating Value" becomes most visible during prototyping and feasibility analysis (Modules 5–6), value considerations are intentionally introduced during opportunity recognition and revisited iteratively throughout the semester. This cyclical framing reinforces that stakeholder impact influences problem definition, alternative generation, trade-offs, and validation criteria rather than serving as a final-stage evaluation metric.

2.3 Design Philosophy and Inclusivity

The course design is grounded in the premise that entrepreneurial mindset development is closely tied to student autonomy, psychological safety, and a sense of belonging. Drawing on inclusive teaching practices emphasized in KEEN workshops, the redesigned course intentionally incorporates structured individual ideation prior to team convergence, allowing all students to generate and articulate ideas independently before group discussion. This sequencing helps mitigate dominance effects and supports more equitable participation during collaborative decision-making, alongside structured tools for respectful communication and multiple opportunities for reflection and iteration.

This approach aims to reduce dominance effects in teams, elevate diverse perspectives, and foster ownership of design decisions. By reinforcing psychological safety and a sense of belonging, these conditions support sustained engagement and motivation in project-based learning environments. [8]

3. Assessment Methods

This Works-In-Progress paper focuses on indirect measures of entrepreneurial mindset development collected through entry and exit student surveys and open-ended reflection prompts. Sixteen students completed the survey instrument; the cohort was almost evenly split between mechanical/materials engineering and electrical/computer engineering majors and organized into five interdisciplinary teams. Survey instruments were intentionally designed to capture students' perceptions of ownership, iteration, communication, and value creation dimensions repeatedly identified in prior course iterations as barriers to successful design engagement. While the present study utilizes predominantly indirect measures, these instruments were developed as precursors to future direct assessments aligned with KEEN competencies and design process outcomes [3, 4, 9]

The survey included Likert-scale items aligned with KEEN competencies as well as open-response questions addressing:

- Opportunity recognition
- Iterative design and validation
- Team collaboration
- Failure and learning
- Value creation
- Communication and confidence

Descriptive statistics (means, distributions) and qualitative thematic analysis of open-ended responses were used to interpret results. The full entry (pre) and exit (post) survey instruments, including Likert-scale items and open-ended prompts aligned with KEEN competencies, are provided in Appendix A.

In addition to the indirect measures reported in this study, student snapshot posters and final project posters were evaluated using an instructor-developed rubric. Rubric criteria were explicitly aligned with KEEN Entrepreneurial Mindset competencies, including opportunity recognition, connections across technical and non-technical domains, iterative validation, and articulation of value creation. While these rubric-based evaluations constitute a form of direct assessment of entrepreneurial mindset behaviors, rubric scores were not analyzed or reported as part of this Works-In-Progress paper.

Module	Primary Focus	KEEN Competency	Entrepreneurial Behaviors Practiced	Assessment Artifacts
Module 1: Challenge Selection & Framing	Problem identification	Curiosity	Opportunity recognition, exploration of unfamiliar problems. Preliminary stakeholder identification. Initial articulation of intended value. Social and contextual problem framing.	Reflection, survey (Q1–Q3)
Module 2: Background Research & Context	Domain exploration	Curiosity	Independent research, perspective seeking	Reflection, survey (Q2, Q5)
Module 3: Team Formation & Collaboration	Team dynamics	Connections	Integrating multiple perspectives, communication	Reflection, survey (Q6–Q9)
Module 4: Concept Development & Modeling	System design	Connections	Linking technical and non-technical domains	Poster, survey (Q7, Q10)
Module 5: Prototyping & Testing	Implementation	Creating Value	Iteration, trial-and-error, validation	Prototype, survey (Q11–Q13)
Module 6: Refinement & Feasibility Analysis	Design tradeoffs	Creating Value	Stakeholder consideration, affordability, realism	Reflection, survey (Q14–Q16)
Module 7: Communication & Reflection	Knowledge transfer	All 3 Cs	Public presentation, metacognition, learning synthesis	Poster, presentation, reflection (Q17, Q22)

Table 1. Alignment of course experiential modules with KEEN Entrepreneurial Mindset competencies. Each module intentionally targets Curiosity, Connections, and/or Creating Value through specific entrepreneurial behaviors and is assessed using a combination of reflections, presentations, and survey instruments.

4. Results

4.1 Curiosity and Opportunity Recognition

Survey items referenced in this section correspond to the instruments provided in Appendix A. Students reported strong engagement with opportunity identification and exploration of unfamiliar problems. The challenge selection process was rated as effective in encouraging exploration (mean = 3.60/5), and course activities sparked curiosity about previously unconsidered systems and concepts (mean = 3.47/5). Most students reported frequently seeking additional information, research, or perspectives beyond course requirements. [10]

Open-ended responses indicate that students independently identified meaningful real-world problems related to accessibility, affordability, health, and practical application of engineering knowledge. Several students explicitly described selecting problems that were personally relevant or socially impactful, reflecting student-driven opportunity recognition rather than instructor-assigned themes. These findings suggest that opportunity recognition was not incidental, but rather an intentional and visible component of the design process.

4.2 Iteration, Failure, and Validation

Iteration emerged as a central student behavior. Students reported revising their designs based on feedback, testing, or new information frequently or continuously (mean = 3.87/5). Validation strategies included trial-and-error prototyping, troubleshooting circuits, external research, peer feedback, and instructor input. [9, 11]

Students described moments of failure that involved software debugging, circuit malfunctions, mechanical misfits, and scope constraints. Rather than viewing failure as a terminal outcome, students consistently described unsuccessful prototypes and design constraints as opportunities for learning and redesign. This reframing suggests that the explicit entrepreneurial mindset framing helped normalize iteration and uncertainty as expected components of engineering practice, a key distinction from prior implicit implementations of the course.

4.3 Connections and Collaboration

Students reported moderate to strong effectiveness in integrating multiple perspectives within teams (mean = 3.13/5) and a strong understanding of connections between technical and non-technical domains (mean = 3.93/5). Comfort of contributing ideas during discussions was also high (mean = 3.80/5). [8]

Qualitative responses emphasize open communication, being heard by teammates, leadership development, and psychological safety. Several students noted growth in collaboration skills even when team dynamics were imperfect, highlighting the authentic nature of the design experience.

4.4 Creating Value

Students reported that their projects aimed to create value for specific users or stakeholders (mean = 3.80/5) and demonstrated understanding of real-world impact (mean = 3.60/5). Confidence in creating value through engineering solutions was rated highly (mean = 4.00/5). [1]

Open-ended responses reveal nuanced thinking about value, including affordability, feasibility, scalability, and trade-offs between ambition and practicality. Notably, students recognized value even when final products fell short of initial goals, citing learning gains, teamwork experience, and increased realism as meaningful outcomes.

4.5 Communication and Metacognition

Students reported that individual reflections were useful in recognizing learning and mindset growth (mean = 3.60/4). Confidence in presenting work through posters and final presentations was moderate to high (mean = 3.53/5). Most students agreed that the collaborative and open-communication environment encouraged intellectual risk-taking (mean = 3.83/5).

When asked to identify the most important entrepreneurial mindset skill developed, students most frequently cited curiosity, persistence, and creating value. These findings align with established research on feedback as a critical driver of learning and performance improvement [15].

5. Discussion

A key contribution of this work lies in demonstrating that explicitly naming, scaffolding, and assessing entrepreneurial behaviors rather than assuming their emergence can meaningfully influence student perceptions and practices in junior-level design. The findings suggest that ownership, curiosity, and value creation are not automatic byproducts of open-ended projects, but outcomes shaped by intentional instructional design. By making these behaviors visible and assessable, the course reframes entrepreneurial thinking as an integral component of engineering practice rather than an auxiliary skill set. [12]-[14]

The findings further suggest that introducing value creation at the problem-framing stage shaped how students selected challenges, justified design decisions, and evaluated trade-offs, reinforcing that entrepreneurial thinking begins with defining what matters rather than merely optimizing technical performance. Rather than appearing only during feasibility analysis, stakeholder considerations informed opportunity recognition and iterative refinement throughout the semester. This cyclical framing strengthens the theoretical coherence of the model and aligns with design scholarship emphasizing the influence of early problem definition on downstream innovation pathways.

Importantly, students demonstrated metacognitive awareness of these behaviors through reflections and survey responses, addressing a limitation of prior implicit EML implementations. The consistency across quantitative indicators and qualitative narratives suggests that the course design successfully operationalized KEEN outcomes in ways that were recognizable to students themselves. While results are based on indirect measures from a single semester, the convergence of evidence supports the viability of this structured approach as a foundation for further longitudinal and direct assessment research.

6. Limitations and Future Work

As a Works-In-Progress study, this paper is limited to indirect assessment data from one course offering. While the current analysis focuses on descriptive statistics and qualitative themes, the survey instruments developed for this study provide a structured foundation for longitudinal analysis of entrepreneurial mindset development and will be refined through future validation efforts. Future work will incorporate:

- Analysis of direct assessment rubrics aligned with KEEN competencies
- Multi-semester data collection
- Comparative analysis with prior course iterations
- External stakeholder feedback on student projects

These steps will further validate the proposed replicable model.

7. Conclusions

This Works-In-Progress paper presents a replicable instructional model for explicitly integrating EML into a junior-level engineering design course. The contribution of this work lies not in adding new content, but in deliberately structuring and assessing entrepreneurial behaviors within an existing electro-mechanical design framework.

At this stage, several elements of the model are immediately replicable. These include the explicit introduction of the KEEN framework early in the semester, the use of scaffolded experiential modules aligned with the 3Cs, structured metacognitive reflection prompts tied to entrepreneurial behaviors, and the alignment of assessment artifacts (reflections, posters, and surveys) with EML outcomes. These components can be adopted by other instructors without requiring changes to course credit hours, major curricular restructuring, or specialized facilities.

What remains to be tested is the longitudinal impact of the model and the analysis and validation of direct assessment instruments aligned with KEEN competencies. Future work will examine multi-semester implementations, comparative analysis with prior implicit EML course versions, and the use of rubric-based direct measures to evaluate student performance and mindset development. Additional validation through external stakeholder feedback will further strengthen claims of value creation and real-world relevance.

For instructors seeking to integrate entrepreneurial mindset learning into junior-level design courses, this work demonstrates that explicit framing and reflection rather than additional content can meaningfully shift student engagement and perceptions. By making entrepreneurial behaviors visible and assessable, the model offers a practical pathway for embedding EML in design courses that already emphasize teamwork, iteration, and open-ended problem solving, thereby better preparing students for capstone design and professional engineering practice.

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